Correlations of simultaneously acquired SSVEPs with BOLD fMRI response

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Introduction:
Steady-state visual evoked potentials (SSVEPs) are interpreted as the reorganization of spontaneous brain oscillations in response to a stimulus and have been used as markers in clinical neuroscience (schizophrenia, Parkinson's), visual attention, and working memory (Viallatte, 2010). Here, they are being used to construct a paradigm with a timecourse is directly comparable in both fMRI and simultaneously acquired EEG. The contrast of the checkerboard was varied to create a slowly changing envelope signal. We have previously shown that it is possible to separate these slow BOLD changes from non-BOLD drifts (Evans, 2015) in fMRI using multi-echo (ME) fMRI and ME-ICA denoising (Kundu, 2012). We are further investigating the correspondence of the denoised data with the neural response.

Methods:
8 normal subjects (2 male, ages 22-36, median 23, mean 27) were scanned on a Siemens Skyra 3T scanner using a 20 channel coil with MPRAGE (res: 0.9mm) and multi-echo fMRI EPI scans (ipat2, res: 3.5mm, 28 slices, FA 90, TR 2 s, TEs: 14, 23, 46 ms). EEG data was acquired using a 31-channel MR-compatible cap (BrainCap MR), with international 10\20 montage and one unipolar ECG connected to a 16-bit amplifier (BrainAmp MR) and recorded on a dedicated laptop using BrainVision Recorder (BrainProducts GmbH, Germany). A whole field flashing checkerboard reversing at 8 Hz with a central fixation cross was used with varying contrast in the runs shown in the results figures. A 10 minute resting scan was also performed with eyes open and fixated on a crosshair. The fMRI data was processed using ME-ICA (Kundu, 2012), which decomposes the fMRI data using ICA and distinguishes BOLD and non-BOLD components based on a test of linear TE-dependence. Removing all non TE-dependent components specifically removed non-BOLD drifts while preserving BOLD baseline signal changes. EEG artifacts from MRI gradient switching and cardiac pulsation were removed by using a MATLAB-based toolbox (Liu) The EEG signals were then lowpass filtered from 0.5 to 40 Hz and down-sampled to 250 Hz. Independent component analysis (ICA) was applied to the EEG data in order to further reduce remaining artifacts, which were identified through visual inspection of the time course and spatial pattern of individual components. A spectrogram of the cleaned EEG data was calculated for the O1, O2 and Oz electrodes and the power at the flicker frequency of 8 Hz was extracted, averaged, convolved with the hemodynamic response and used for comparison with the fMRI timeseries.

Results:
Figure 1 shows the timecourses for the medn fMRI data and SSVEP envelope at the flicker frequency for all the subjects. On average (thick line) the tasks are readily differentiable, however, not all subjects show an appropriate task-like response. Although the subjects were awake at the beginning of each task, there was no overt vigilance check and SSVEPs are affected by visual attention whereas it appears the BOLD responses is less so. A review of the alpha power in conjunction with the task does show that on average the subjects have higher alpha band fluctuations at rest than during the task, which could be used as a measure of vigilance to explain the reduced EEG response.

Figure 2 shows a direct comparison of the average fMRI and SSVEP traces and they agree well with some differences in contrast response. Notably, the flanking blocks at the end are better resolved in fMRI than in EEG, this is potentially an effect of habituation.

https://ww4.aievolution.com/hbm1501/index.cfm?do=abs.viewAbs&subView=1&abs=2115
Conclusions:
The denoised signal correlated well with simultaneously recorded EEG data indicating detection of true task with fMRI. Therefore, ME-ICA can be used to extract ultraslow fMRI fluctuations of neuronal origin, while excluding confounds due to scanner drift. Additionally, SSVEPs could be a valuable way of constructing tasks that are readily used in both fMRI and EEG to capitalize on the spatial resolution of the former and the temporal resolution of the latter.
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**Imaging Methods:**
- BOLD fMRI
- EEG

**Keywords:**
- Electroencephalography (EEG)
- FUNCTIONAL MRI

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